Callaway GOLF

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TO: Board of Patent Appeals & Interfernces
U.S. Patent and Trademark Office

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ATTN.: Eric W. Hawthorne

FROM: Michael Catania
Intellectual Property Counsel

RE: Application Number: 09/877,835
Appeal Number 2006-1941

Dear Mr. Hawthorne:

Attached are the pages from the reference that you requested.

Respectfully submitted,

Michael A. Catania
Attorney for Applicants
Registration Number 36,474

Science and Golf III

PROCEEDINGS OF THE 1998 WORLD SCIENTIFIC CONGRESS OF GOLF

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Human Kinetics

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essentially all high-performance golf balls are near the maximum allowable launch speed, aerodynamics is the primary determining factor in carry distance on driver shots. The dimples uniquely determine the aerodynamic performance of a golf ball under specific launch conditions.

Wakes are formed behind objects that have a shape or orientation that causes the flow to separate. As the air flows around the surface of the ball, it does not have enough momentum to overcome the adverse pressure forces created by the curvature of the surface, and the flow will separate from the surface and rejoin the free stream. The point at which this occurs is called the separation point. The region behind the sphere, between the two separation points, is an area of low pressure. In other words, the average pressure on the golf ball on the downstream half of the ball is considerably less than on the side facing the airflow, or the upstream side. The net result of the force created by this pressure difference is called form drag, and is essentially a resistance to the movement of the ball through the air. The form drag is directly related to the location of the points of separation on the ball and the formation of the wake. Wakes are characterized by velocities less than the velocity in the undisturbed, or freestream, flow and grow laterally in the downstream flow direction. The edges of the wake are regions of high shear due to large changes in velocity over small distances.

In the present study, extensive hot-wire velocity measurements were made in the wake of a spinning golf ball to examine differences in the wake characteristics of balls having significantly different lift and drag characteristics. These differences in lift and drag are characterized by ball performance on driver shots measured on the test range at the Dunlop Maxfli Sports Corporation Outdoor Research Center in Westminster, SC, USA.

EXPERIMENTAL FACILITY AND MEASUREMENTS

The subsonic flow examined here was generated in a variable-speed, suction type, open-circuit wind tunnel located in the Department of Mechanical Engineering, Clemson University. The wind tunnel has a contraction ratio of 9:1. The range of velocity used during testing was 62.98 to 65.43 m/s, corresponding to Reynolds numbers based on ball diameter from 174,329 to 181,103. The wind tunnel test section dimensions are 57 cm (22.4 inches) square by 240 cm (94.5 in) long. Honeycomb and screens, followed by a settling section, are used to reduce turbulence levels in the test section and promote a uniform velocity distribution in the wind tunnel. The tunnel is driven by a Buffalo Forge centrifugal blower having a 1.13 m wheel diameter (size 890) with a rated capacity of 1130 (40,000 cfm) at 14 cm (5 + in) of water. The wind tunnel exhibited a minimum working turbulence intensity of 0.44% at 20 m/s. A sting was employed to hold the ball in the air stream and to spin it at a known rate. The spinning sting provided a drive rod encased in a streamlined housing. Balls were mounted on the drive rod by drilling a stepped hole through the center of the ball. A DC variable-speed motor and a variable, regulated DC power supply controlled the spin rate. Using a stroboscope to measure the peripheral velocity, the ball was set to 3000 rpm ± 25 rpm.

Hot-wire anemometry was used to measure the component of the velocity in the downstream direction, or the streamwise velocity component. Hot-wire anemom-

etry employs an electronic circuit to maintain a noble metal wire at an elevated, constant temperature. The power required is a direct indication of the air speed. A single TSI tungsten 1260-T1.5 constant-temperature hot wire was used to measure velocity. A traversing mechanism was employed to accurately locate the hot wire in the wake of the spinning golf ball. The ball was spun around its vertical axis. Velocity measurements were made in a horizontal plane located at the center of the ball, and perpendicular to the vertical spin axis. Streamwise velocity data was obtained in the horizontal plane at the vertical center of each ball. Velocity measurements were made at x/D of 0.2, 0.5, 0.75, 1, 1.25, 1.5, 1.75, and 2, where D is the ball diameter, and x is the distance measured in the streamwise direction, with $x = 0$ at the rear (downstream) surface of the ball. At each x/D location, twenty-four velocity measurements were made on a base grid having 5 mm intervals. During these measurements the probe was moved in a direction perpendicular to the flow and in a horizontal plane; this direction is termed the spanwise direction. Relative to the center of the ball, this grid was displaced 1.5 cm toward the side of the ball spinning against the wind to account for the wake deflection in that direction. In addition, more detailed measurements were made in the wake based on information gained from the initial measurements made on the base grid described above. A refined wake region was identified based on an increase in the RMS value of the velocity, and a corresponding decrease in the mean velocity from the freestream data. The number of spanwise measurements ranged from a minimum of 48 to a maximum of 64 measurements over the 11.5 cm traversing span.

RESULTS

As summarized in table 55.1, flight testing of Balls 1, 2, and 3 indicated significant differences in the aerodynamic performance, with a resulting range of variation in carry distance for driver shots from 7 to 8%. As such, these balls should provide an opportunity to examine whether significant differences in lift and drag correlate with measurably different wake characteristics.

As previously discussed, flow separates from the surface of the ball creating a low-pressure region at the rear of the ball. Separation points located further toward the rear of the ball yield smaller drag forces due to pressure, and smaller wakes. An important fundamental characteristic of flow around a golf ball is related to the spin,

Table 55.1 Aerodynamic Performance From Flight Testing

Ball identification	Normalized Distances and Trajectory Height		
	Carry distance	Total distance	Trajectory height
Ball 1	0.919	0.884	1.000
Ball 2	1.000	1.000	0.74
Ball 3	0.934	0.969	0.60